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resolved in that direction. But the present test is not as fair a test as the preceding one. As *real* proper motion diminishes we may expect to find an increasing number of stars at every stage. Hence, the number of stars which can be *brought down* to a particular figure by the effect of the Sun's motion will probably be always less than those that can be *raised to* it by the same effect; and if we take all the stars having a given velocity (irrespective of sign) in the direction of the North Pole of, say, 0″.30 per annum, our list will contain a larger number of raised stars than of lowered stars. I do not, therefore, see any valid reason for inferring that the Sun is moving towards the North Pole with a velocity exceeding one half of the average star-motion resolved in that direction. I hope some other member of the Society will take up the subject and arrive at more extensive and satisfactory results. I thought the method in any event worth mentioning, and, with our growing knowledge of the spectroscopic velocities of the stars, I think the prospect of being able to measure the Sun's motion in miles per second cannot be regarded as by any means hopeless.

STAR CATALOGUES.

By Elliott Smith.

The determination of the positions of the stars has long been a matter of much concern to astronomers, and star catalogues have from time to time been issued giving their position with greater or less precision, according to the skill of the observer, the accuracy of his instruments, or the purpose for which the catalogue was made. As a result we have many star catalogues at our disposal, and it may not be out of place to call the attention of A. S. P. readers to a few of these at this time.

Without going into detail it will, no doubt, be sufficient merely to mention the earlier catalogues. They are so inaccurate as to be of no practical value, and they have no connection with modern catalogues, with the exception that the names or numbers assigned to the stars in some of them are in use at the present day. HIPPARCHUS, PTOLEMY, AL-SUFI, and ULUGH BEIGH in order concerned themselves with star places; and the names of TYCHO BRAHE, HALLEY, and HEVELIUS are familiar to students of astronomical literature in this connection. All of the catalogues which they published, with the exception of that of HIPPARCHUS, which has not been preserved, have been compiled and published in the thirteenth volume of the Memoirs of the Royal Astronomical Society, with an introduction giving a description of each.

The middle of the seventeenth century marks the beginning of an epoch of unprecedented activity in the history of catalogue-making, and it may be said to have been formally inaugurated at the founding of the Greenwich Observatory in 1675. This new activity received its impulse from the direct necessity to navigators and explorers of a better knowledge of the positions of the stars and of the motion of the moon and planets.

It was possible for the navigator to determine his latitude at sea with accuracy sufficient for his purpose by simply observing the height of the Pole Star, but the problem of longitude at sea for many years baffled the most expert navigators, and mathematicians were not able to solve it. Handsome prizes were offered by nations whose conquests and colonies in the new world rendered their navigation important, and many methods were suggested. When finally the method of determining longitude by *lunar distances* was proposed, it was found that the knowledge of the positions of the stars and of the motion of the moon and planets was so inaccurate as to render the plan impracticable.

When this report was made to Charles II of England, he at once ordered that an observatory be founded to determine accurately the positions of the fixed stars and the motions of the moon and planets, and in other ways to assist navigation. Systematic observations of the positions of the stars thus begun at Greenwich are being continued by its observers at the present day. Other astronomers, inspired by this new incentive, have been active in meridian observations, so that in the past two centuries such a wealth of catalogues have accumulated that it would be manifestly impossible in so short an article as this to mention more than a small fraction of them. All we can hope to do is to call the attention of the reader to a few of the catalogues found in an observatory library of to-day, of interest from the standpoint of history or of importance to the advancement of the science of astronomy.

The so-called British Catalogue, derived from the observations of FLAMSTEED, the first Astronomer Royal, was published in 1725 in the third volume of the *Historia Celestis*. It was revised and enlarged by BAILY in 1835, and as thus completed contains over 3,300 stars for the epoch 1690. In the column of the catalogue headed "Difference from Bradley" it is interesting to note that in Right Ascension a difference of five minutes of arc is not uncommon, and in Declination the difference in some cases is three minutes.

BRADLEY published no catalogues himself, but while at the Greenwich Observatory he made such accurate observations and such complete records of them that they have been of great value to the science of astronomy. MASON made a catalogue of 389 stars from BRADLEY'S observations, whose places were published in the Nautical Almanac for 1773.

It was left to BESSEL, however, to do the first thorough work upon the observations made by BRADLEY. With the method of reduction which he himself had perfected BESSEL derived the positions of more than three thousand stars from the observations made by BRADLEY from 1750 to 1762. The epoch is 1755, and the catalogue was published in 1818 in BESSEL'S *Fundamenta Astronomiæ*. This catalogue was of much importance to the science of astronomy at the time of its publication. By a comparison with the catalogues of BESSEL'S own time the precession was more accurately determined and the proper motions of many stars became known, making it possible to predict their places for the future with accuracy.

Exact observations are of value at any time, but that their value increases as time goes by is well exemplified by the work of Dr. AUWERS upon the Bradley stars in the latter half of the nineteenth century. With all the refinements of reduction known to modern times and with corrections derived from a thorough investigation of the Bradley instruments, Dr. AUWERS re-reduced the whole mass of BRADLEY'S observations made between 1750 and 1762. The epoch of the catalogue, as in BESSEL'S, is 1755, and it contains 3,222 stars. A comparison of the Bradley positions, thus derived, with observations of the same stars made ninety years later furnished over three thousand proper motions. The work of Dr. AUWERS upon the Bradley stars is published in three volumes: the first contains the determination of the constants of the instruments and the corresponding corrections; the second the results of observation in Right Ascension and zenith distance, and the third the star catalogue. The third volume was published in 1882, the second in 1888, and the first recently came from the publishers under date of 1903.

LACAILLE is the author of three catalogues of stars observed at the Cape of Good Hope. His work attracted considerable popular attention, for he was among the first astronomers to make an expedition to the southern hemisphere for the purpose of observing the southern sky. The first catalogue contains 398 stars for the epoch 1750; the second is a catalogue of 9,766 southern stars for the same epoch; and the third is of 515 zodiacal stars for 1765. The second catalogue was printed about the middle of the nineteenth century at the expense of the British association. The observations for the third catalogue were reduced by BAILY, but not so accurately as the state of the science warranted, and the catalogue has not been of as much service as it might have been.

MAYER'S catalogue of 998 zodiacal stars was published at Göttingen in 1775. It may be found in the fourth volume of the Memoirs of the Royal Astronomical Society. D'AGELET'S catalogue was intended to be a very comprehensive one. It was contemplated to determine the positions of all the stars of the northern hemisphere down to the ninth magnitude. As finally completed the catalogue contains 47,400 stars for the epoch 1800. The positions as given by this catalogue are not very exact, but it has been useful because of being so extensive. The thirty-six fundamental stars of MASKELENE, fifth Astronomer Royal, were probably the most accurately determined of any up to his time, and they were in general use as reference points by astronomers in the early part of the nineteenth century. It may be of interest to note here that MASKELENE was the first observer who, in taking a star's transit, divided the seconds into tenths. Observers previous to his time gave simply the nearest second.

The first catalogue of PIAZZI was published in 1803. It contained 7,648 stars, the thirty-six stars of MASKELENE being used as fundamental. Some doubt being thrown upon the Right Ascensions of the Maskelene stars, PIAZZI resolved to make a catalogue founded exclusively upon his own observations. He first constructed a preliminary standard catalogue of 120 stars, published in 1607, to be used as fundamental in the catalogue which followed. This catalogue of 7,646 stars was published in 1814, and at that time was considered of great importance. The observations and reductions were made by PIAZZI himself, and the refraction corrections were derived by him exclusively from his own observations.

All of the Piazzi stars were reobserved by TAYLOR of Madras for the epoch 1835. Most of the southern stars of PIAZZI may be found in the Cordoba General Catalogue for 1875, and the northern Piazzi stars are contained in the *Astronomische Gesellschaft* Catalogue for the same epoch. The reobservations of the Piazzi stars for 1900 completes the list of four epochs for those stars well distributed throughout the century, the southern stars having been observed by Professor TUCKER of the Lick Observatory, and the northern stars by Professor PORTER of the Cincinnati Observatory for the last epoch. A large number of the Piazzi stars have been included in special lists as zodiacal stars and many have been observed as fundamental. The original observations are being reduced anew by Dr. HERMAN S. DAVIS. As a result of all this there is a large amount of material outstanding in regard to the Piazzi stars, and it is expected that a discussion of it will yield results of no little interest and value to astronomy.

Professor AIRY, while Astronomer Royal at the Greenwich Observatory, derived the positions of 4,243 stars from the observations of STEPHEN GROOMBRIDGE for the epoch 1810. The resulting catalogue is of circumpolar stars, and has been of importance for that reason. Those astronomers who have taken up the task of forming a normal system or fundamental catalogue have had constant recourse to the Groombridge catalogue.

BESSEL has been mentioned in connection with the Bradley reductions, but BESSEL himself conducted a valuable and extensive series of observations at the Königsberg Observatory.

Between the years 1821 and 1833 he observed a large proportion of the stars down to the ninth magnitude, quite uniformly distributed in the zone — 15° to + 45° of Declination. The observations were reduced by Professor WEISSE, of Cracow, and published in two volumes at the expense of the St. Petersburg Academy of Science. The first volume contains the stars between — 15° and + 15° of Declination, and the second those between + 15° and + 45°. The two volumes contain over 62,500 stars for the epoch 1825. ARGELANDER continued the observations according to BESSEL'S plan from + 45° to + 80°. OELTZEN reduced ARGELANDER'S observations, and the resulting catalogue in two volumes gives the position of nearly 26,500 stars for the mean epoch 1842.

In connection with star catalogues, however, ARGELANDER will be longest remembered for his work upon the *Bonn Durchmusterung*. By an extensive series of observations he obtained the approximate positions of all the stars to magnitude 9 between + 90° and — 2° of Declination for the epoch 1855. The three volumes in which his work is published contain about 324,200 stars. SCHÖNFELD continued the Durchmusterung to Declination — 23°. His results are published in one volume, which constitutes the fourth volume of the Bonn Durchmusterung. It contains nearly 133,700 stars for the common epoch 1855.

The work of observing the southern stars on the same plan from Declination — 23° to the South Pole yet remained to be done, and the task was undertaken by the Cordoba Observatory. The actual northern boundary at which their work began was Declination — 22°, so that there is a zone of one degree in common between the catalogues of SCHÖNFELD and Cordoba. SCHÖNFELD included all stars to the nine and one half magnitude in his catalogue, while the Cordoba Durchmusterung contains all the stars to magnitude 10 and many even fainter. So far three volumes containing the approximate positions of 489,600 stars between — 22° and — 52° have been published. The epoch is 1875. The work of cataloguing the remaining portion of the southern sky is still in progress at Cordoba. If it is as rich in stars as the portion already observed it is estimated that the Cordoba Durchmusterung completed will contain over 800,000 stars, making a total of considerably more than a million and a quarter stars for the entire sky as catalogued in this great work.

The catalogue in two volumes known as the Gould zones properly represents the results first sought by the founder of the Cordoba Observatory. This catalogue contains the positions of 73,160 stars for 1875 between —23° and —80° of Declination. It includes stars to magnitude 9½, and is in reality a continuation of observations in the southern hemisphere according to plans employed by BESSEL and ARGELANDER in the construction of their catalogues of the northern sky, described above. The observatory was organized by Doctor GOULD, as the National Observatory of the Argentine Republic, and it has been carrying on some extensive pieces of work, of which the Durchmusterung is an example.

While early in the nineteenth century the northern sky was receiving a great deal of attention, the southern sky was not wholly neglected. LACAILLE's observations in the southern hemisphere have already been mentioned. The Rev. F. FALLOWS, astronomer at the Cape, published in volume CXIV of the *Philosophical Transactions* a catalogue of 273 south circumpolar stars for 1824. BRISBANE's catalogue of 7,385 stars published in 1835; RÜMKER's catalogue of some 12,000 stars for 1836; HENDERSON's Declinations and Right Ascensions of 172 and 174 stars respectively for 1833; JOHNSON's catalogue of 606 southern stars for 1830; TAYLOR's general catalogue containing 11,000 stars for 1835, and his catalogue of 97 Principal Fixed Stars for 1845,—all these were among those most in use by astronomers interested in the accurate positions, and in the magnitudes and proper motions of southern stars up to the middle of the last century. Other later catalogues of southern stars that have been in general use and of recognized value to astronomy are the Argentine General Catalogue for 1875, containing all of the brighter stars of the sky within 100 degrees of the South Pole, the catalogue of 1,963 stars by GILLIS, MACLEAR's catalogue of 1,159 stars for 1860, STONE's catalogue of 78 south circumpolar stars and his catalogue of 12,441 stars for 1880.

For stars in the northern hemisphere there is such a wealth of observation that to enumerate the catalogues that are of value would require a small volume. We shall therefore mention only a few of those which have been most used by astronomers. Perhaps the catalogues to which we should give our first attention are those which from time to time have been compiled from the Greenwich observations. The Greenwich Twelve-Year Catalogue of 2,156 stars is founded on observations made at Greenwich for the twelve years beginning in 1836. The first six years of observation were reduced to 1840, and the other six years to the epoch 1845. The Six-Year Catalogue of 1,576 stars for 1850, the Seven-Year Catalogue of 2,022 stars for 1860, the new Seven-Year Catalogue of 2,760 stars for 1864, the Nine-Year Catalogue of 2,263 stars for 1872, the Ten-Year Catalogue of 4,059 stars for 1880, the Five-Year Catalogue of 258 fundamental stars for 1890, and a new Ten-Year Catalogue for the same epoch, are monuments to the industry, accuracy, and skill of the Greenwich observers.

In point of accuracy and uniformity in reduction the Pulkova catalogues have not been surpassed. The epoch of their first catalogue is 1845, the Right Ascensions and Declinations being published in separate volumes. The number of stars contained is about 375. Four other catalogues whose epochs are separated by ten-year intervals have been much used. The Pulkova catalogue for 1855 has 3,542 stars; the catalogue for 1865 is published in volume XII of the Pulkova Observations. H. ROMBERG derived a catalogue of 5,634 stars from the Pulkova observations for 1875, and NYREN's Standard Catalogue of Declinations comes from the same source.

What Greenwich and Pulkova have been to the northern hemisphere, the observatory at the Cape of Good Hope has been to the southern. An enumeration of the epochs of the catalogues which have been published at the Cape will give an idea of the activity of that observatory in catalogue making. 1833, 1840, 1850, 1860, 1880, 1885, and 1890 are epochs of catalogues which have been compiled and published from the Cape Observatory.

Other observatories which may be mentioned as having been especially active in meridian observations are Munich, Oxford, Melbourne, Harvard College, Albany, Washington, Cincinnati, Madison, Berlin, and Paris.

The *Astronomische Gesellschaft* Catalogue is one of the most important of recent date. It will contain, when completed, all the stars to the ninth magnitude included between + 80° and — 23° Declination. For observation the sky was divided into zones of five and ten degrees, different observatories becoming responsible for a larger or smaller zone according to their facilities for carrying on the work of observing. The object in each case was to have the zone assigned to any one observatory as near its zenith as possible to avoid errors in applying refraction corrections. The epoch is 1875 for the northern catalogues, 1900 for the southern.

The catalogue for the northern sky between — 2° and + 80° is all but complete. The second volume containing stars between + 70° and + 75° has not yet been published. It may be of interest to note that two observatories of the United States—Albany and Harvard College—took part in this great work. The first volume of the catalogue for the southern zone recently arrived at the Lick Observatory, and it is hoped that the date of completion of the others may not be far distant.

NEWCOMB and AUWERS are authors of fundamental catalogues most in use at the present time. PORTER and BOSSERT have published standard catalogues of proper motion stars.

The discussion and comparison of star catalogues has become a recognized field of labor for astronomers, and results of no little importance have been derived from it. BOSS, NEWCOMB, AUWERS, CHANDLER and others have concerned themselves in this line of work.

At one time the making of star catalogues was considered the most important branch of astronomy. Researches in the line of what we understand as physical astronomy were looked upon with very little sympathy by the old-line astronomers. We would say in conclusion, however, that the remarkable development which the so-called physical astronomy has undergone in the last half century has only enhanced the importance to the science of an exact knowledge of the positions of the stars, and at present catalogues are being made which aim to give the positions of stars with still greater accuracy. Older catalogues give a clue to the proper motions, so that even though we have a large and ever increasing number of catalogues they are all of use in advancing our knowledge of the sky.